6GEM

ATE-BioEM Center

UNIVERSITÄT DUISBURG ESSEN

WP4.8: 6G.Bioelectromagnetics Interactions

Electromagnetic Power Absorption in Skin Tissues : Age and Body Region Variations Across 5G/6G Frequencies

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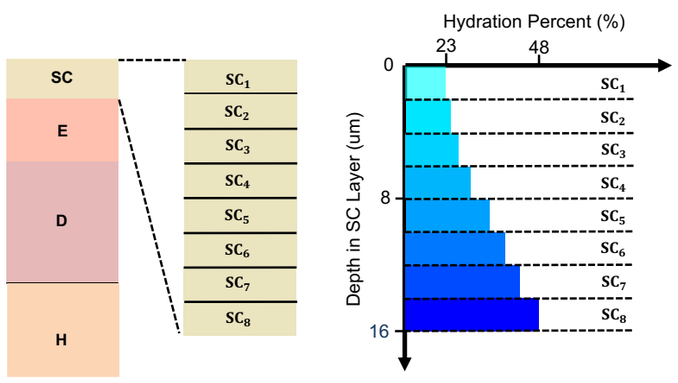
1. Introduction

This investigation focuses on the modeling of skin samples from five age groups in the same ethnic population (Macedonian), targeting the abdominal and anterior forearm regions. The skin structure is represented using five homogeneous tissue layers – stratum corneum (SC), epidermis (E), dermis (D), hypodermis (H), and muscle tissue (M) – and illuminated by an electromagnetic plane wave in the 5G/6G frequency range (1–300 GHz). Detailed analyses were carried out with the Finite Element Method (FEM) using the COMSOL Multiphysics simulation software. Findings deliver accurate data on power absorption within each skin layer, including the corresponding penetration depths of electromagnetic fields, and shows age-specific absorption variations for the two different body regions.

2. The Stratified Skin Model and Dielectric Properties

■ The dielectric properties of each skin layer:

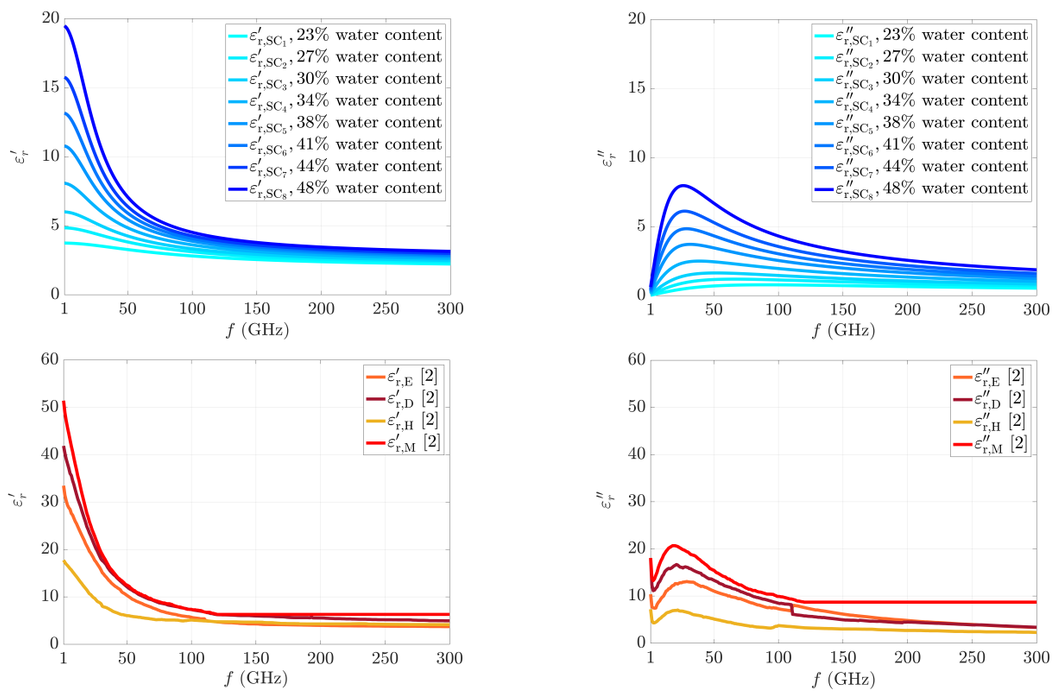


- The dielectric properties of each sublayer of SC were calculated using Bruggeman's Effective Medium Theory [1] across the frequency range of 1–300 GHz.

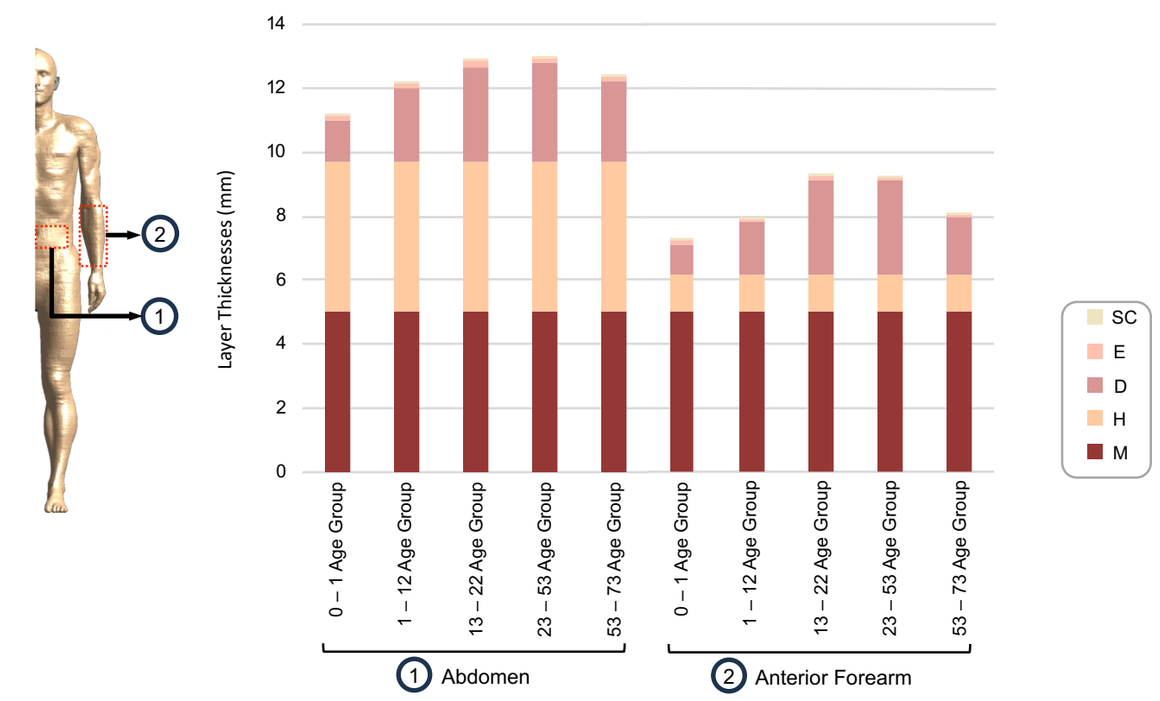
$$\eta_1 \frac{\varepsilon_1 - \varepsilon_{eff}}{\varepsilon_1 + \varepsilon_{eff}} + \eta_2 \frac{\varepsilon_2 - \varepsilon_{eff}}{\varepsilon_2 + \varepsilon_{eff}} = 0$$

- The measurement results reported in [2] were used to determine the dielectric properties of the E, D, H and M layers in the frequency region of 1-300 GHz.

■ The real and imaginary part of dielectric function of the SC, E, D, H and M tissue layer:



3. Age and Body Region-Based Variations in Skin Layer Thickness



- The total thickness of the SC for the skin samples is 16 um [3].
- The thicknesses of the E and D have been taken from the mean values reported for 5 different age groups in the anatomical region of the abdomen and the anterior forearm [4].
- The thickness for the H layer have been adopted from [5], while the specifications for the M layer thickness were based on the standards outlined in [6].
- The mass densities of the SC, E, D, and H layers were sourced from [7], while the mass density of the M layer was obtained from [8].
- The 23-53 age group`s abdomen exhibits the thickest skin (12.94 mm), while the anterior forearm of the 0-1 age group displays the thinnest skin (7.25 mm).

4. Penetration Depths

■ Penetration depths of the electric field within skin samples at 7 distinct frequencies:

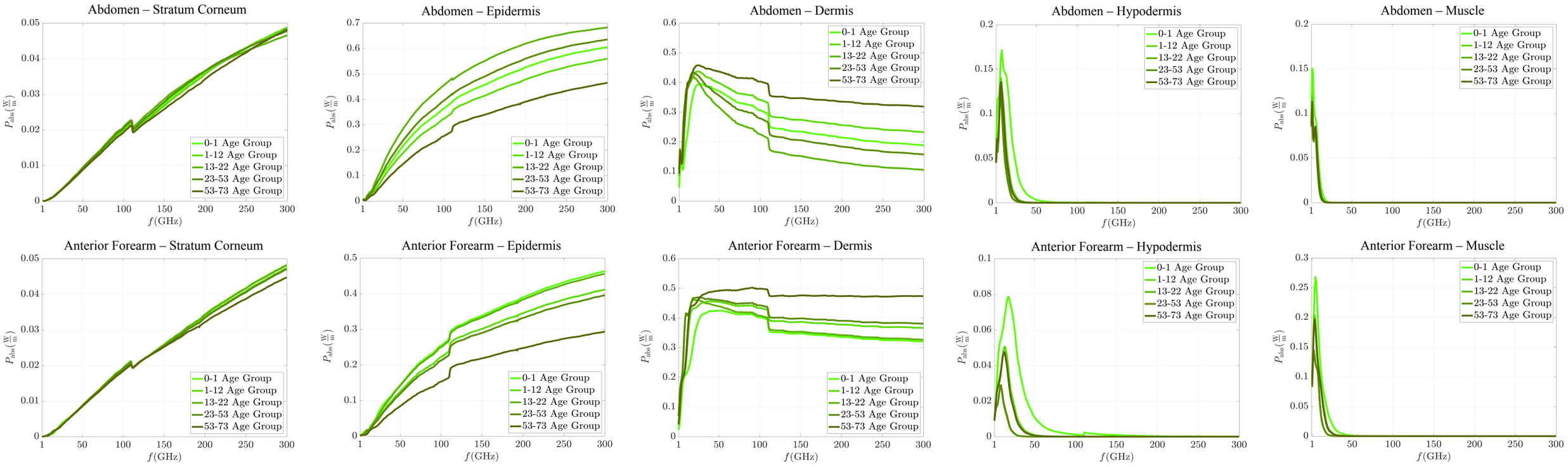
Body Region	Age Groups	Penetration Depths (mm)						
		1 GHz	6 GHz	24 GHz	71 GHz	110 GHz	200 GHz	300 GHz
Abdomen	0 - 1	11.15*	9.14	1.25	0.42	0.31	0.23	0.19
	1 - 12	12.14*	9.44	1.19	0.38	0.29	0.20	0.17
	13 - 22	12.89*	9.48	1.21	0.37	0.29	0.20	0.19
	23 - 53	12.94*	9.44	1.20	0.38	0.26	0.18	0.17
	53 - 73	12.34*	9.44	1.19	0.38	0.28	0.21	0.17

Body Region	Age Groups	Penetration Depths (mm)						
		1 GHz	6 GHz	24 GHz	71 GHz	110 GHz	200 GHz	300 GHz
Anterior Forearm	0 - 1	7.25*	7.25*	1.26	0.42	0.30	0.24	0.20
	1 - 12	7.84*	7.44	1.20	0.41	0.29	0.23	0.18
	13 - 22	9.16*	7.82	1.21	0.39	0.30	0.22	0.18
	23 - 53	9.11*	7.80	1.20	0.40	0.30	0.23	0.18
	53 - 73	7.97*	7.44	1.18	0.40	0.28	0.24	0.19

*In this case, the power density does not decay to e^{-2} of its initial magnitude, the penetration depth exceeds the layer thickness and therefore the entirety of the skin thickness is recorded.

5. The Absorbed Power in each Skin Layer

■ Age-specific and body region-specific variations in power absorption across skin layers:



6. Literature

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